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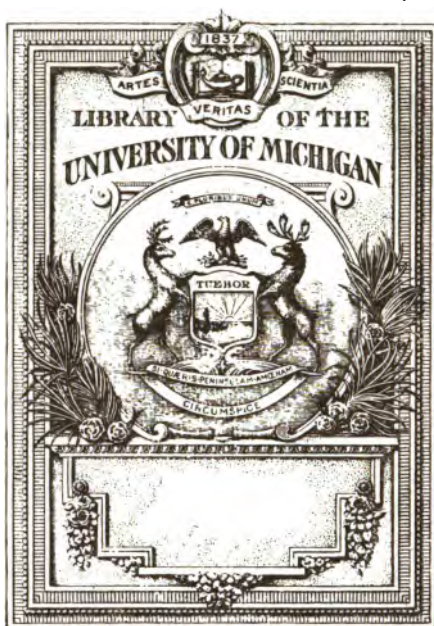
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THE ENGINEERING BUILDING.

PROCEEDINGS OF THE SOCIETY OF ARTS.

Massachusetts Institute of Technology.

A TECHNICAL DESCRIPTION
OF THE
ENGINEERING BUILDING
OF THE
INSTITUTE OF TECHNOLOGY.

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A Technical Description of the Engineering Building of the Institute of Technology.

BY PROFS. F. W. CHANDLER (ARCHITECTURE); G. LANZA (MECHANICAL ENGINEERING); G. F. SWAIN (CIVIL ENGINEERING); AND MR. S. H. WOODBRIDGE
(HEATING AND VENTILATING).

At a meeting of the Society of Arts held in the Engineering Building, Thursday, May 8, 1890, the New Engineering Building was described as follows:

Prof. CHANDLER said: The Engineering Building of the Institute of Technology is built on Trinity Place, a short distance from the other buildings of the Institute. The structure measures 148 feet by 52 feet, and has six stories. Its height of 85 feet is the extreme limit allowed by the building laws when a wooden construction is used. Its position on the lot was very carefully considered in regard to future additions to the south on the property of the Institute; and, by mutual agreement with the abutters, there will always be a clear area of 30 feet to the north.

The scheme of the building is what is known as modern mill construction. A row of cast iron columns, placed eight feet from center to center, runs lengthwise of the building, giving spans of twenty-four feet from column to wall. The strength of the brick wall is concentrated in buttresses opposite the columns, and thinner walls unite them, and because these thinner walls are not necessary for the stability of the building, the greater part of this space is occupied by windows, the heads of which extending between the beams, as there are no ceilings, to the underfloor give that high light which is the most effective in lighting a large room. A pair of southern pine beams extends from each column to each side wall. These doubled beams

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are in all cases bolted together with eight $\frac{3}{4}$ -inch iron bolts to each pair, leaving a space of one inch between for ventilation, kept open by iron washers. The beams are framed to fit snugly around the columns, and the ends of the abutting timbers are fastened together by dogs of $\frac{3}{4}$ -inch iron, the ends of which are turned down and driven into holes in the beams. These timbers are also fastened at the under side by lag screws through the caps of the columns. The other ends rest on cast-iron plates one inch thick, and are carried into the wall eight inches, and one inch of air space is left about the ends for ventilation. To tie these beams to the walls a one-inch bolt is put through each pair of beams eight inches from the wall, and at the same time through the eye of another one-inch bolt which lies between the timbers, the nut end being on the outside of the building, and pressing against a cast-iron washer. Across these paired beams are carried plank under-floors of spruce, four inches thick in the basement and three inches thick elsewhere. These planks are laid with splines. The upper floors throughout are of maple and $\frac{7}{8}$ inches thick. Between the lower and upper floors, in addition to the asbestos paper required by law, are three thicknesses of heavy deadening felt, and two of tarred paper.

The construction of the roof is like that of the floors.

It does not yet appear by whom the slow-burning construction, as applied to mills, has been evolved, or when was first made use of heavy timbers set wide apart carrying a solid floor. But for a long time after these floors were in use, even in Lowell, the roofs were bad either in form or structure until Mr. William B. Whiting, the Vice-President of the Boston Manufacturers Fire Insurance Co., suggested the adoption of what is called the deck roof, constructed like the floors, and the Engineering Building is a development of the Mutual Underwriters more than anyone else.

The structure throughout is of unusual strength, for the aim was to have a building which should be sufficiently free from vibration when the heavy machinery was running in the basement, to admit of experiments being made there, requiring delicate measurements, and because the four upper floors were to be chiefly used for draughting rooms. The iron columns decrease in size from the one in the basement measuring $11\frac{1}{2}$ inches in diameter with a $1\frac{1}{2}$ -inch shell to the one in the sixth story, 6 inches in diameter with an inch shell. These

columns resting on each other have their ends carefully turned in a lathe to ensure perfectly accurate bearings,—the head of one column having a seat countersunk $\frac{1}{4}$ inch to receive the foot of the next column. In the mill proper these columns are of wood, but, on account of the great weight to be carried in this structure, much valuable space could be saved by using iron.

The beams of the basement floor measure each 11 inches by 18, those of the first floor 10 inches by 18, those of the second 7 inches by 16, and those above 6 inches by 16, and those of the roof 6 inches by 14.

There are no boilers in this building, the steam for heating and for power is brought from the boilers in the basement of the Rogers Building, about a thousand feet away, through a six-inch pipe buried under ground. The pipe is first wrapped in asbestos, and for further insulation it is inserted in a wooden log.

The heating system is partly direct and partly indirect, and with the indirect part ventilation is obtained by means of a Sturtevant blower. Nearly all the radiators have automatic valves, the temperature of the room regulating the steam supply to the radiator.

In connection with the heating should be mentioned that the window sashes of the north, east, and west sides of the building, and also a large skylight on the roof measuring 80 by 16 feet, lighting the upper draughting room, are double glazed, making a great saving in the expenditure of heat.

The exterior design is very simple, all effect being obtained by the principle of construction. The solid basement from which rises the long buttresses or pilasters, connected at the top by semi-circular arches, and the upper story with its thinner wall forming an attic, describes the design. And it is effective enough; it tells its story truly. The material is rough brick with a small amount of Long Meadow stone trimmings.

A heavy block granite foundation rests on 725 piles, averaging 40 feet long. All the heavy machinery in the basement have their piled foundations distinct from that of the building.

There can hardly be a more fire-proof structure. First, its isolation; then there is not a concealed space anywhere, no furrings on the walls,—the brick is the only finish, no ceilings, with their dangerous air spaces the depth of the floor joists,—the staircase is built open in

the same way,—the ventilation and heating ducts running from the basement out through the roof are of iron. Water is on every floor, and the standpipe is carried to the roof. An iron staircase, built in a brick tower, runs to the roof to serve as fire escape.

The building is occupied by the Mechanical Engineering and Civil Engineering Departments. The two lower stories are the laboratories of the Mechanical Engineering Department, and this department also has the two middle floors, which are devoted to drafting and recitation rooms. The two upper stories contain similar rooms for the Civil Engineering Department, and the library common to both departments.

THE LABORATORIES.

Prof. Lanza was next introduced to describe the laboratories.

Prof. LANZA said : These laboratories are now called the Engineering Laboratories, and the building is called the Engineering Building, because it is especially devoted to the engineering work of the school, both the general and the special. Thus, in its recitation rooms are taught the classes in mechanism, in thermo-dynamics and steam engineering, in hydraulics, and in strength of materials, all of which may be called general engineering studies, as all these subjects are taught, to a greater or less extent, to the students of civil, of mechanical, of mining, of chemical, and of electrical engineering. Besides this, all the drawing-room work of the students of these courses is done in this building, and all the purely professional work of the civil and mechanical engineering courses is carried on here ; this including practically all the *engineering* work proper of the above stated courses. Hence it follows that it is the building where the purely engineering work is done for all departments of the school.

The Laboratories are really an aggregation of the following : —

1. A laboratory devoted to experimental work upon the strength and other resisting properties of materials used in construction.
2. A laboratory of steam engineering.
3. An hydraulic laboratory.
4. A laboratory where other engineering experiments are made, but which is not yet sufficiently differentiated to be divided into its component parts.

The objects to be accomplished by these laboratories are the following : —

First. To give the students practice in such experimental work as any engineer is constantly liable to be called upon to perform in the practice of his profession,—as boiler tests, engine tests, power determinations, etc.

Second. To give the students some experience in carrying on original investigations in engineering subjects with such care and accuracy as to render the results of real value to the engineering community.

Third. By publishing from time to time the results of such investigations, to add gradually to the common stock of knowledge.

The two lower floors of the building are entirely devoted to the Engineering Laboratories, thus increasing their capacity from about 5,550 square feet, as in the Rogers Building, to about 13,900 square feet. Cuts of these laboratories are shown here, and the following statement of the apparatus they contain is copied from the twenty-fifth Catalogue of the Institute:—

“The laboratory for testing the strength of materials is furnished with the following apparatus. An Olsen testing machine of 50,000 pounds' capacity, for determining tensile strength, elasticity, and compressive strength. A testing machine of the same capacity for determining the transverse strength and stiffness of beams up to 25 feet in length, and the framing-joints used in practice. Machinery for the measurement of the strength, twist, and deflection of shafting while running and under the conditions of practice. Machines for time tests of the transverse strength and deflection of full-sized beams; for testing the tensile strength of mortars and cements, and of ropes; for testing the effect of repeated stresses upon the elasticity and strength of iron and steel; for determining the strength and elasticity of wire; for determining the deflection of parallel rods when running under different conditions. Also, accessory apparatus for measuring stretch, deflection, and twist.

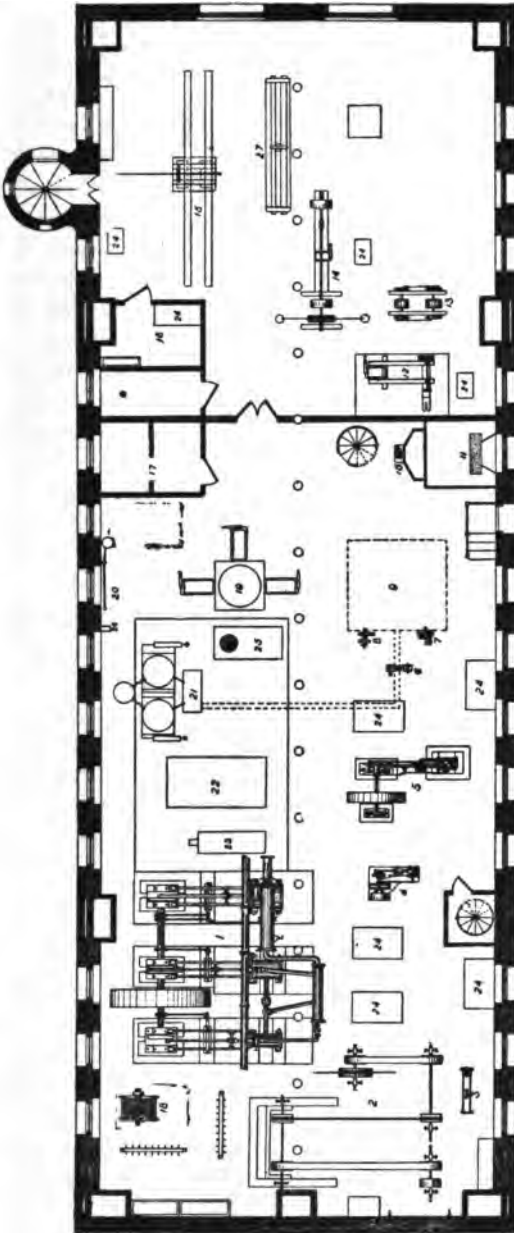
“The steam laboratory contains,—a triple expansion engine, with cylinders of 9 inches, 16 inches, and 24 inches diameter respectively, and 30 inches stroke, arranged in such a way as to be run single, compound, or triple, as desired for the purposes of experiment. This engine is of the Corliss type, and was built by E. P. Allis & Co. It will have a capacity of about 150 horse-power when running triple, with an initial pressure of 150 pounds in the high-pressure cylinder. It is connected with a surface condenser and all the other apparatus necessary to adapt it to the purposes of accurate experiment.

"This laboratory also contains a 16 horse-power Harris-Corliss engine, and an 8 horse-power engine, used for giving instruction in valve-setting, etc. It is also equipped with several surface condensers, steam pumps, calorimeters, mercurial pressure and vacuum columns; apparatus for determining the quantity of steam issuing from a given orifice or through a short tube under a given difference of pressure; apparatus for testing injectors; and with indicators, planimeters, gauges, thermometers, anemometers, and other accessory apparatus.

"The engineering laboratories are also provided with a number of friction brakes; with machinery for determining the tension required in a belt or rope to enable it to carry a given power at a given speed, with no more than a given amount of slip; with three transmission dynamometers; with a complete set of Westinghouse air-brake apparatus, including the parts belonging on the car and on the locomotive; with cotton machinery as follows, namely, two cards, a drawing frame, a speeder, a fly frame, a ring frame, and a mule, as well as accessory apparatus. There are also available for the purposes of experiment, in connection with the work of these laboratories, two horizontal tubular boilers, one large Babcock and Wilcox boiler, and a Porter-Allen engine of about 80 horse-power, all situated in the Rogers Building; also another boiler, a 40 horse-power Brown engine, a number of looms, and other apparatus in the workshops on Garrison Street."

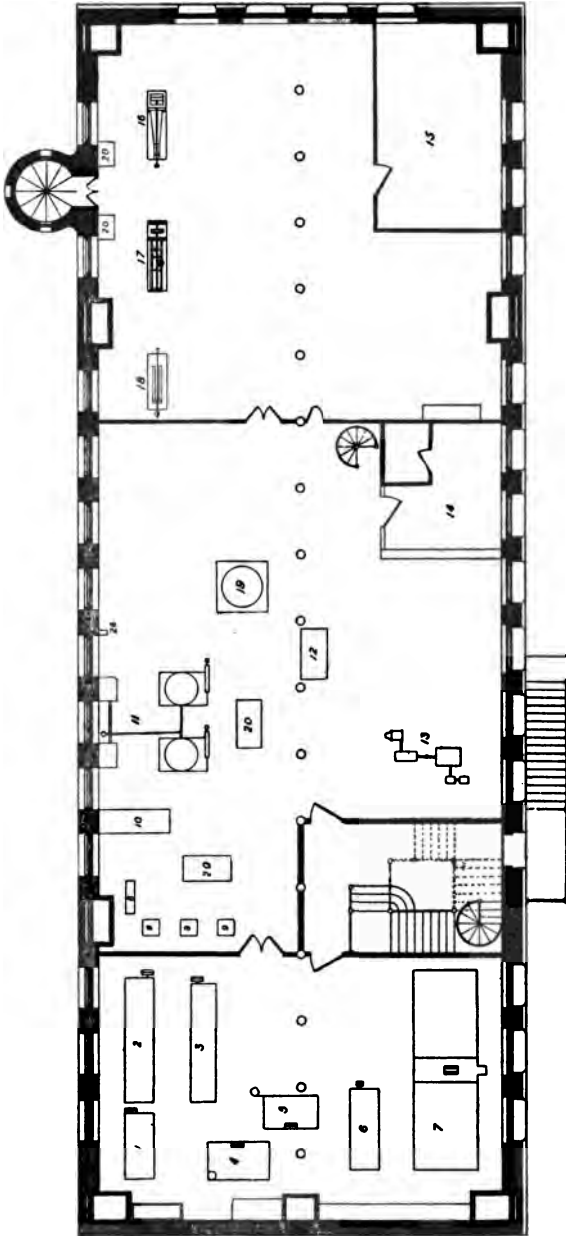
The most important addition to the equipment of these laboratories is that of the triple-expansion engine, inasmuch as it is the first triple-expansion engine of a practical size that has ever been arranged for making experiments; and by its means the laboratories are placed in a position which will enable them to do work for the triple engine of a character similar to that done for the compound engine by the United States Naval Engineers in 1874, and also to make such researches with a triple or a compound engine as were made upon single engines by Hirn, Hallauer, and others.

The laboratory with its present equipment furnishes the means, — 1st, of accommodating the number of students that now need this instruction, with an opportunity for some growth; 2nd, of giving good laboratory instruction to the students; 3rd, of carrying on investigations of importance in the engineering line. All this can be done, inasmuch as the building is adapted to the purposes of an engineering laboratory, — a fact which was never true of the Rogers Building.



BASEMENT, 150 X 50 FEET.

1. Triple Expansion Engine, 150 H. P.
2. Rope and Belt Transmission Testing Machine.
3. Engine Lathe.
4. Kendall Engine, 8 H. P.
5. Harris-Corliss Engine, 16 H. P.
6. Steam Pump.
7. Rotary Pump.
8. Centrifugal Pump.
9. Tank.
10. Fan Engine.
11. Steam Pipes for Heating Air.
12. Rope-Testing Machine.
13. Parallel-Rod Machine.
14. Shaft-Testing Machine.
15. Fifty Thousand Pounds Beam-Testing Machine.
16. Cement Room.
18. Dynamo, 500 Lights.
19. Wrought-Iron Tank for Hydraulic Experiments (6 feet diameter, 27 feet high).
20. Hydraulic Stand-Pipe (10 in. diam., 86 feet high).
- 21, 22. Cisterns.
23. Condenser.
24. Tables.
25. Turbine-Wheel and Tank.
26. Mercury Column.
27. Apparatus for Time Test of Wooden Beams.



FIRST FLOOR.

1. Drawing-Frame.
2. Speeder.
3. Fly-Frame.
4. Carding Engine.
5. Carding Engine.
6. Spinning Frame.
7. Mule.

8. Calorimeters.
9. Calorimeters.
10. Calorimeters.
11. Injector and Weighing Tanks.
12. Tank for Turbine-Wheel.
13. Westinghouse Air Brake.
14. Office.

15. Office.
16. Olsen's Fifty-Thousand Pounds Tension Machine.
17. Repeated-Bending Machine.
18. Cement-Testing Machine.
19. Tank for Hydraulic Experiments.
20. Tables.
26. Mercury Column.

THE HYDRAULIC LABORATORY.

At the close of Prof. Lanza's remarks, Prof. G. F. Swain was introduced, who described the Hydraulic Laboratory.

Prof. SWAIN said: The erection of the new engineering building of the Institute of Technology, to be occupied by the departments of Civil and Mechanical Engineering, offered an opportunity for a considerable extension in the Engineering Laboratories, and an attempt has been made to improve this opportunity by laying the foundation for a laboratory for hydraulic experiments, which should be so arranged as to permit of the carrying out of any experiments in hydraulics which it is practicable to perform within walls. Hydraulic experiments on a large scale must necessarily be performed out of doors, since the measurement of large quantities of water requires apparatus and appliances which cannot be accommodated within walls. Thus, the weir experiments of Mr. Francis, at Lowell, were made by taking the water from one of the canals, and using a lock as a measuring basin; those of Messrs. Fteley and Stearns, at South Framingham, were made by using a portion of the Sudbury River Aqueduct as a measuring basin; the orifice experiments of General Ellis, at Holyoke, were made in connection with the fall between two levels of the canal at that place; and the recent elaborate and careful experiments by Mr. Freeman on the flow of water through fire hose, the discharge of nozzles, and the height of jets, were made at Lawrence, where the hydrant system of one of the mills, as well as the city water supply, could be made use of.

But while experiments such as these are clearly excluded from among those which can be made in connection with an hydraulic laboratory in an institution of learning, there remain a large number which can properly be conducted within doors with the aid of suitable apparatus, and which, though they may be on a small scale as regards the quantities of water employed, nevertheless offer a large field for scientific investigation. The new laboratory of the Institute, as already stated, has been planned with a view to affording opportunity, as the work is extended, for carrying on any experiments which are thus practicable; that is to say, in the following directions:—

1. Experiments on the flow through orifices of small size, both free and submerged, and either sharp-edged, rounded, or fitted with

inside or outside mouth-pieces of various kinds, and under heads ranging as high as above seventy feet.

2. Experiments on the flow of water over weirs of small size, either free or submerged.

3. Experiments on the loss of head in small pipes of various kinds.

4. Experiments on the loss of head due to bends, curves, valves, diaphragms, or other obstructions causing sudden changes of velocity.

5. Experiments on the distribution of velocity in different parts of a liquid cross-section, either of a jet from an orifice, of a sheet discharged over a weir, or of a liquid flowing in a pipe.

6. Experiments on different water meters, including Mr. Herschel's Venturi meter, as well as the ordinary forms in the market.

7. The testing of small turbines and of various other small motors.

8. Experiments on the pressure of jets against plane or curved surfaces, and on the resistance of standing water to the motion of surfaces of different shapes through it.

9. Experiments on the siphonage of traps, and on other matters connected with plumbing arrangements of houses.

The development of a laboratory which shall admit of experiments in all these lines must necessarily be slow and expensive, and the laboratory in the Institute, being only a few months old, is not yet fully equipped to carry on any of these experiments excepting those on the flow of water through orifices. It is believed, however, that the foundation has been laid for the rapid development of research in the remaining directions which have been enumerated, and the object of the present paper is briefly to describe and illustrate the apparatus thus far provided or proposed.

In order to be able to work with large heads, and to be independent of the city water supply, as well as to provide for the varied experiments enumerated, it was first necessary to erect a tank and standpipe. The tank is shown in Figure 1. It is made of "Shell" steel $\frac{1}{4}$ inch in thickness, is 5 feet in diameter and about 28 feet high, resting on a concrete foundation and extending up through two floors. It consists of six courses of steel, with girth seams single riveted, and longitudinal seams double riveted, and with heads of $\frac{1}{8}$ -inch steel dished, as shown in the figure. It is provided with orifices as follows:—

In the lowest course, a man-hole 24 inches by 12 inches at M; at P, a flanged nozzle with elbow for connecting to 10-inch standpipe, as shown in Figure 15.

In the second course, a 10-inch orifice at G, a second at F, a third at D, and a fourth at C. The orifice at F may be used, if desired, for connecting with a small turbine placed below the floor. That at G is for experiments on submerged orifices. Those at D and C are for experiments on free orifices, or for connecting lines of pipe with the tank. Enclosing the orifice at G, an angle-iron and two bent plates are attached to the side of the tank, as shown, to which a wooden tank extending horizontally and resting on the floor is to be attached. In this wooden tank will be placed a weir, and the water will flow through the submerged orifice at G, or through a submerged mouth-piece, either inside or outside, and either converging or diverging, and will then flow over the measuring weir. The orifice C is fitted for experiments on free orifices, as will subsequently be described. The orifice D is to be fitted with a piece to which pipes can be attached as desired, thus enabling the losses of head at diaphragms, valves, curves, etc., to be studied. On the same level with the orifices D and G connections are made for mercury gauges.

In the third course, a $1\frac{1}{2}$ -inch orifice at G" and another at C", nearly above the large orifices G and C. These small orifices are for the shafts of the hand-wheels for raising the gates over the large orifices, as will presently be explained.

In the fifth course, orifices similar to those in the second course; and in the sixth course, orifices similar to those in the third course; thus rendering it possible to carry on experiments simultaneously upon two floors of the building. The top of the tank is provided with a flanged nozzle for connecting with the 10-inch standpipe, as shown in Figure 15.

The size of the tank is such that, with the orifices which it will be practicable to use, the velocity in the tank will be so small that it may be neglected, and the disturbance due to the inflowing water from the standpipe will also be small. Nevertheless, two gratings have been arranged, one at the top and one at the bottom. These gratings consist of plates of $\frac{1}{8}$ -inch iron perforated by $\frac{1}{2}$ -inch holes about an inch apart. They are made in three pieces, and rest upon angle-iron brackets riveted to the inside of the tank. The tank itself rests upon cast-iron supports, as shown in Figure 1.

The general arrangement of the tank and standpipes is shown in Figures 15 to 18. Figure 15 shows the plan of the sub-basement, with the location of the tank, the rotary pump, and the steam pump. The tank *a* is connected, as shown, by the top connection *e* and the lower connection *f* to the 10-inch wrought-iron standpipe *b*, which, as shown in Figure 17, extends to the top of the building, and is closed at the top. The connection *f* is tapped by the small pipe *g*, by means of which the water may be drawn out of the system into the cistern *h*. The pumps take water from this cistern *h* and deliver it into pipe *k*, which, as shown in Figure 17, is arranged to carry it directly to the standpipe through the valve *s*, or to the 3-inch pipe *c* through the valve *t*. For use in the hydraulic experiments, the valve *s* is closed and the valve *t* opened, the water being thus delivered into the 3-inch pipe *c*. From this pipe the flow into the 10-inch pipe is regulated by the valves *n*, which enable the head in the 10-inch pipe to be maintained at an almost perfectly constant level. Any excess of water overflows through the pipes *m* into the discharge pipe *d*. The pipe *c* therefore serves as a regulator of the head, and it has been found to fulfil its purpose admirably. Attached to the standpipe *b*, and running from floor to ceiling, in each story, is a glass gauge placed in front of a graduated scale reading to hundredths of a foot. These gauges are enclosed in wooden boxes, which may be opened on the front and on one side, and which are placed so as to receive light directly from adjacent windows. The water is taken by the pumps from the cistern *h*, passes through pipes *k* and *c* and through the valves *n* into the standpipe *b*, thence through the connection *e* or *f*, or both, into the tank, from which it is discharged through orifices, or in any other way desired, and the discharge measured. Measurements are made by weighing the quantity of water discharged in a given time, the water being returned to the cistern *h*, and thus used over and over again.

The same apparatus, by suitable arrangement of the valves, will be employed in making tests of the pumps.

The city water pipe is connected with the standpipe system at *x*.

The soil pipe *dd* is arranged with single and double Y's in a way which will allow the carrying out of all kinds of experiments on the siphonage of traps, as mentioned under head 9 on page 138. This pipe is arranged with an ordinary trap at the foot, as shown in Figure 16, and it discharges into the cistern *h*, as shown in Figure 15.

The details of the arrangement for measurements with simple free orifices are shown in Figures 2 to 14. In experiments of this description it is of course essential that the orifice shall be placed in a plane surface. It was therefore necessary to arrange the apparatus so that the curvature of the tank itself should not affect the flow. For this purpose a composition casting α (Figs. 2 and 3) is drawn up to the tank by eight $\frac{3}{8}$ -inch bolts, as shown in Figure 3, which are screwed into the hub of the casting. The greater part of the casting is only $\frac{1}{4}$ inch in thickness, with eight strengthening ribs, as shown in Figure 2. In this casting is placed a piece, c , which is held in position by a ring-nut, dd , which can be screwed or unscrewed by a spanner. When it is desired to use large or long orifices the piece c will contain the orifice, and by having various pieces c , with orifices of different shapes and sizes, numerous experiments may be carried out. The composition casting α is thickened on one side to $\frac{3}{8}$ inch, as shown in Figures 2 and 3, to allow of the insertion of a sliding piece by means of which the horizontal dimension of a rectangular orifice may be varied, keeping the vertical dimension constant. When small orifices are to be used, it is not desirable to have them cut in as large a piece as the piece c . This piece c , therefore, as shown in Figure 3, is arranged to take a second piece, o , held in place by a second ring-nut, d' . Small orifices are made in pieces like the one o , as shown in Figure 3, and are of different sizes and shapes.

It is desirable that one orifice may be removed and another substituted in its place without completely emptying the tank. For this purpose a gate is designed to slide on the back of the casting α , so that, when it is desired to remove one orifice, the gate may be lowered and the water thus shut off, and a new orifice substituted in place of the old one. The gate may then be raised and the experiments continued. This gate and the fittings connected with it are shown in Figures 4 to 14. Figure 4 shows a view of the gate from the inside, Figures 5 and 6 horizontal cross-sections, and Figure 7 a vertical cross-section. The gate is of cast iron, ribbed as shown, and is arranged to slide in guides bolted at the bottom to the casting α , and at the top to the tank. These guides are shown in Figures 8 to 11. In order that the gate may be raised without having to overcome the friction due to the pressure of the water over the entire surface of the gate, the rod r , by which the gate is raised, is attached to an

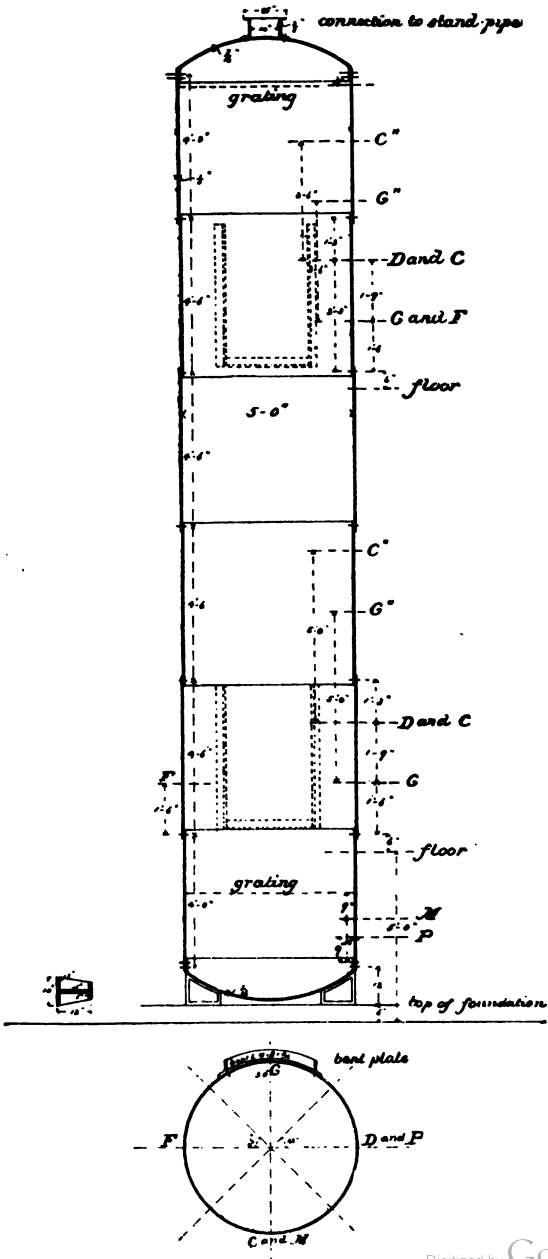
angle-iron, L (Figs. 4 and 7). When the gate is to be raised from the position shown in Figure 7, the angle-iron L is first raised until it strikes against the rib above it. This raising of L opens the orifice d , thus allowing water to pass through the gate, and equalizing the pressure on the two sides, except over the small ring forming the bearing surface, the friction due to the pressure on which is, therefore, the only friction to be overcome. The discharge orifice may be meanwhile closed by a plug from the outside, if necessary. When the gate is lowered, its own weight carries it down until it reaches the stop s . The rod is then forced down, closing the orifice d . Figures 12 to 14 show the hand-wheel, shaft, and stuffing box, by means of which the gate is raised, and require little explanation. The rod shown in Figure 7 is in its upper part a rack running in the space r (Fig. 12).

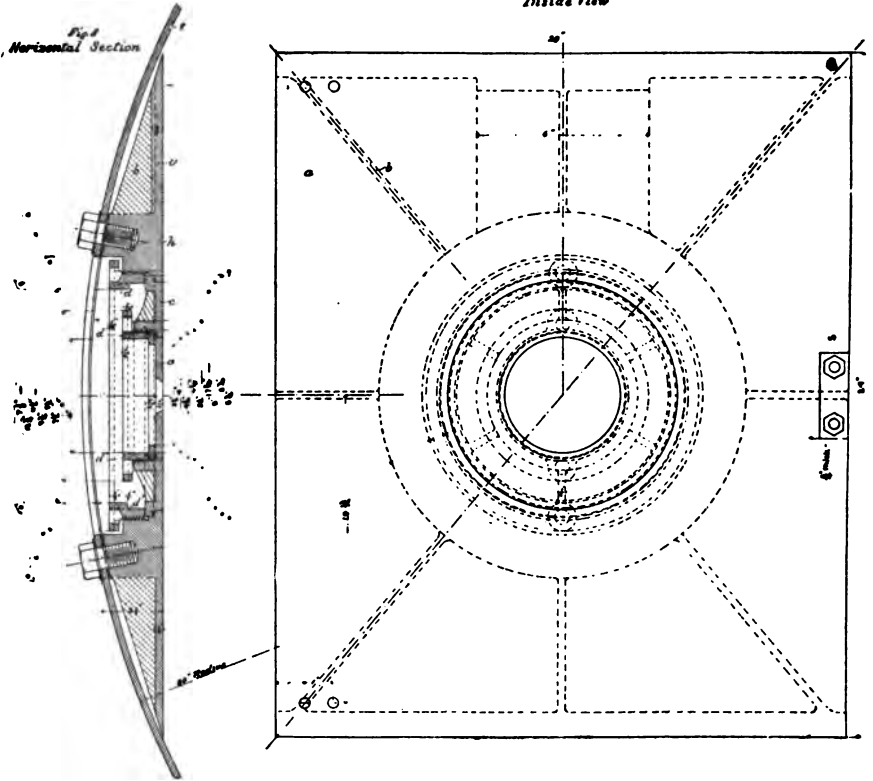
Only one further point calls for explanation regarding the arrangement of the gate and stuffing box, namely, the modifications necessary for the case of inside mouth-pieces. When such mouth-pieces are used, the gate as shown would of course be inapplicable, and a new seat must be provided for it, so that it will pass clear of the inside mouth-piece. It is intended to accomplish this by bolting on to the composition casting a (Fig. 2) a circular channel-shaped rib, and adding new guides for the gate, thus making its seat at any desired distance back of the inside face of the casting. At the same time, in Figure 12, the pinion will be removed from the position shown, and placed outside of the bearing, where the collar is shown in the figure, and the collar placed on the inside. A new guide for the rack will then be bolted on, as shown by the dotted lines.

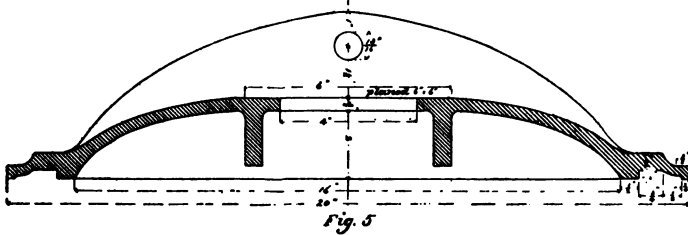
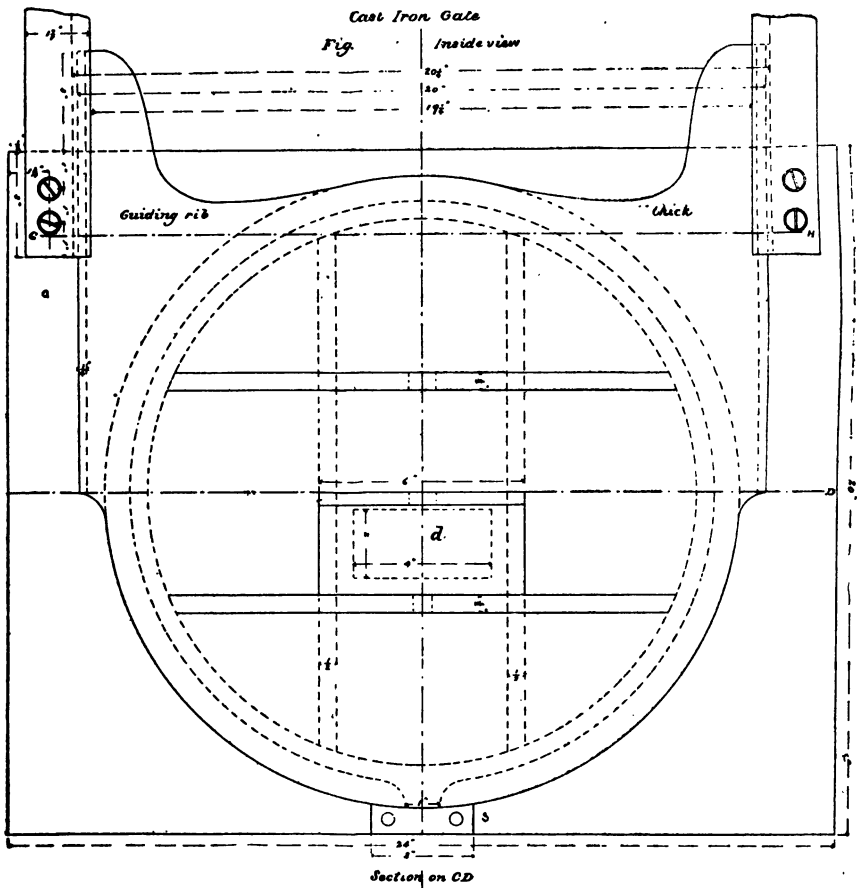
As the new engineering building has been occupied only since February, 1890, and the hydraulic apparatus is thus but a few months old, the only apparatus thus far in use is that for measuring the flow through simple, free orifices, and for making tests of pumps. It is hoped, however, that the remaining apparatus will be provided in the near future. The tank and the standpipe system already procured furnish the foundation, and upon them the other apparatus may readily be built up. Experiments upon meters and upon motors may also be carried out without difficulty; and, in fact, the possible lines of research are so varied that it is hoped that the establishment of this laboratory may lead to many useful results, and that it may contribute in some measure to the advancement of hydraulic science.

Steel Tank

Fig. 1.



*Details of House Casting*Fig. 2
Inside View



Section on GH.



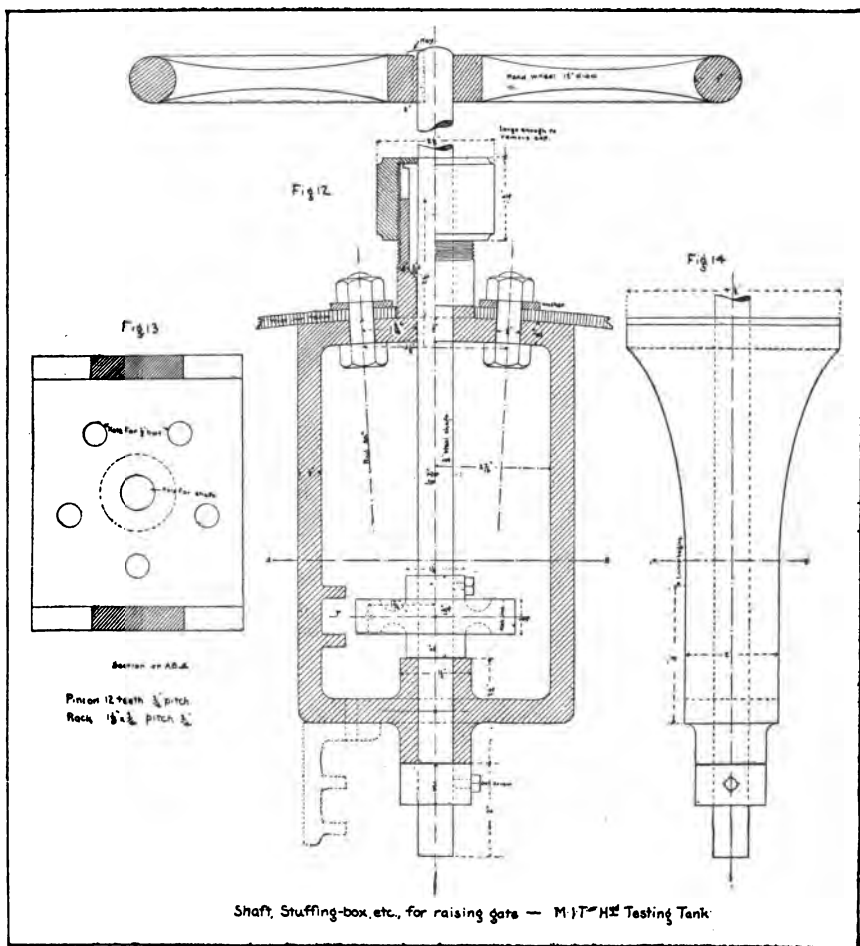
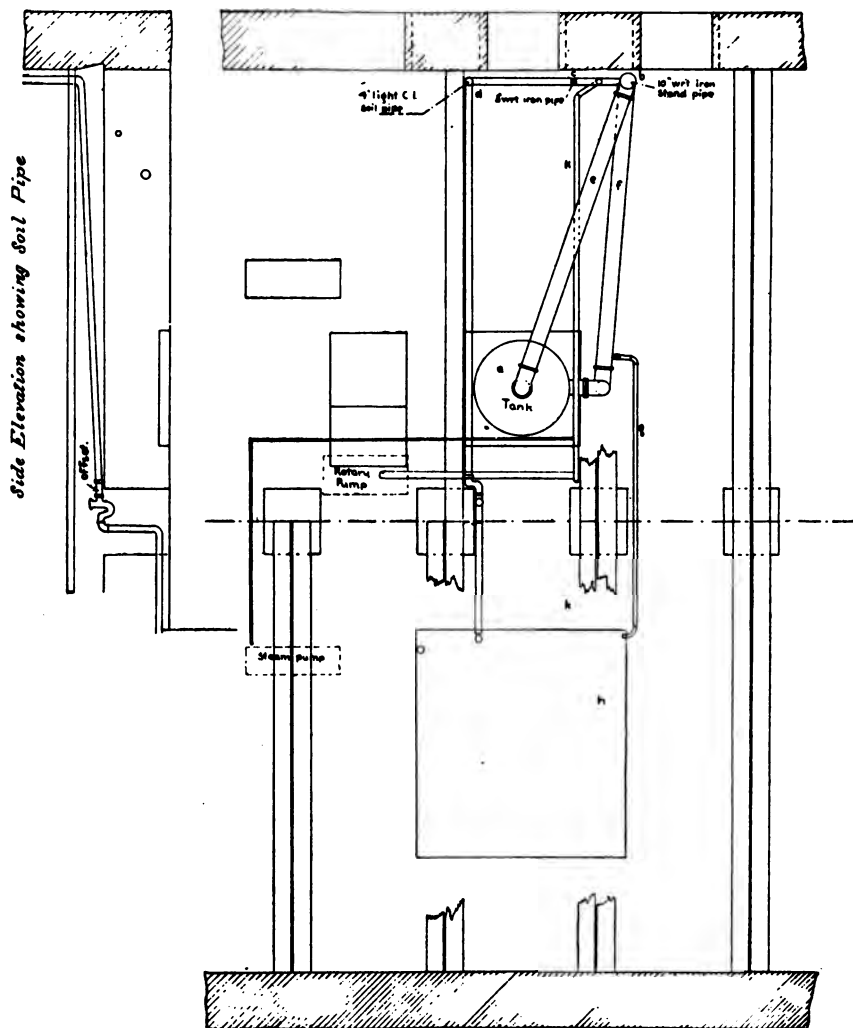
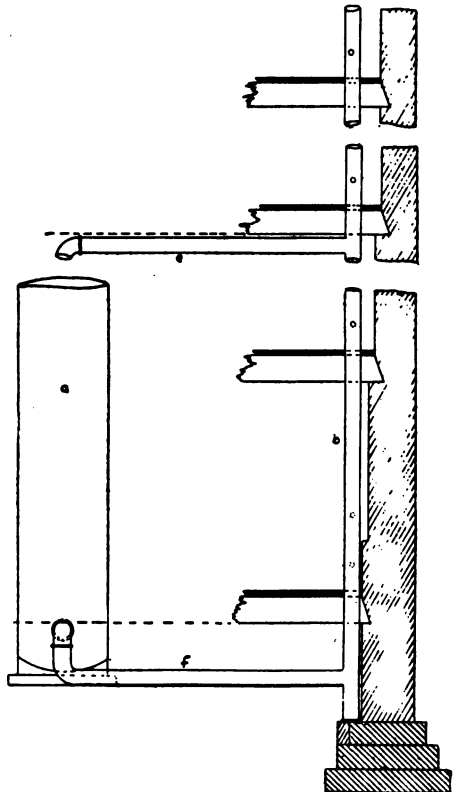
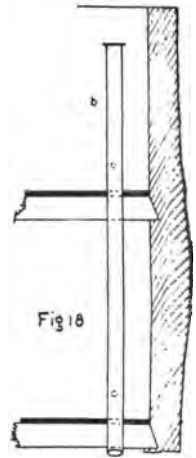
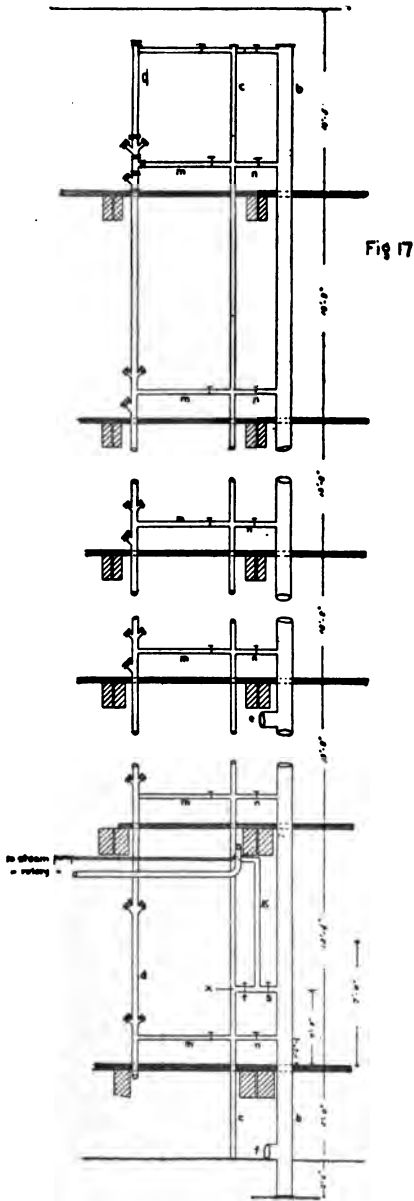


Fig 15

Plan of Sub-basement



HEATING, HEAT REGULATING, AND VENTILATING.

At the close of Prof. Swain's paper, Mr. S. H. Woodbridge was introduced, who described the System of Heating, Heat Regulating, and Ventilating.

Mr. WOODBRIDGE said: This building is without interior walls other than light partitions, and all available external wall space is demanded for piers and windows. Locations were allowed for eight vertical flues (F) Fig. 1, varying from 9 to 12 sq. ft. in cross-section, for the supply and discharge ventilation of the thirty and more rooms. The rooms were arranged by their intended users with only partial reference to the fixed location of flues, and connecting air ducts were disapproved as unsightly. The great value of the basement floor space imposed a limit of 10' x 12' on the area to be surrendered to ventilating purposes. The use of the concrete floor of the sub-basement for apparatus, above and about which the basement floor is removed, precluded the use of this space as a distributing air chamber, and compelled the building of a continuous duct about the perimeter of the sub-basement, with one cross duct beneath the fan and into which it discharges at A-A, Fig. 1. The main duct, except where engine beds encroach upon it, is 15 sq. ft. in cross-section. The cross duct has nearly twice that area. The control of the air quantities to be moved in one direction or another within these ducts is effected by movable deflectors, one under the fan, and one at each end of the cross duct, Fig. 1.

The perimeter ducts have for three of their sides the foundation wall of the building, the sub-basement concrete floor, and the wooden floor of the basement. The fourth side is of galvanized iron, secured by nailing to wooden strips set in the concrete and nailed to the wooden floor and beams. A free use of elastic cement was made in all joints between metal and wood, and of paint in all locked or other joints of the sheet metal, and provision made for a possible settling away of the concrete from the wooden floor.

To clear the laboratory ceiling and the floor space of all possible obstructions and the unsightly appearance of piping, the steam mains and branches, traps, etc., are placed within the air conduits. All such steam pipes are carefully pitched and drained and covered. In spite of the latter precaution the temperature of the air in transit from the fan to the most remote flues is raised some 12°.

The eight vertical ducts are of necessity made to serve the dual purpose of supply and discharge. To adapt them to such purpose, a diaphragm is fixed in such way as to provide two channels having areas proportioned to the quantities of fresh and spent air to be moved through them to and from the successive stories, Fig 3. These diaphragms are made of sheet iron, which is secured by methods effectually preventing the leakage of air from the plenum into the exhaust conduits. Wherever practicable, the diaphragm is so placed as to remove the supply conduit from the outer walls, and to bring the discharge conduit against them.

Because of the small space occupied by the entire system, velocities of the air moved must be high. To secure to each register of the lower stories its proportion of air, and to prevent its going by such register under the momentum of its movement, deflectors are used, the area of each and the angle at which it is set controlling the air volume issuing from each register. Similar deflectors, set in a reverse position, are used for the outlets from the upper stories. To thoroughly break up and diffuse the swift flow of cool air in solid current from the register, diffusers, such as are shown in Fig. 1, are used with gratifying success.

The building accommodates some three hundred students, and the air supply is nearly 2,000,000 cu. ft. per hour, the fan running at 250 revolutions. The students are massed now here now there in class rooms, drawing rooms, and laboratories. Provision is made for a corresponding distribution or concentration of air supply, but the results without such alteration are so generally satisfactory that the valves are not used. Within the best filled rooms the largest proportions of carbonic acid thus far found are $\frac{1}{10000}$ to $\frac{1}{7500}$, and the uniformity of the proportions in all parts of the rooms has been found exceptional.

The warming is effected by three systems. Because of the large amount of steam work done in the basement, air must be supplied in large quantities, and at a temperature ranging from 45° to 55° , according to laboratory work and outside conditions of weather. The eight distributing flues cannot supply air to the several floors or rooms at different temperatures. They must supply it at the temperature required by that room above the basement most easily warmed to the point desired. Therefore, it becomes necessary to provide means for supplying air through one system of conduits to the basement at, say

50°, and to all rooms above the basement at 70°, and to further warm the air by direct means in such rooms as require supplementary heat.

The air is heated before it reaches the fan to 50°, a "Standard" metallic thermometer mounted in the fan case indicating the temperature, which is controlled by regulating the steam pressure in the coil. In moving under pressure through the sub-basement conduits the air leaks generously, as was anticipated, through innumerable small vents, the current being no where sensible, though the aggregate volume amounts to some 750,000 cu. ft. per hour. Reaching the base of the flues, the air passes through steam coils so made and placed that the flue area is not obstructed. The control of steam to these coils is by means of the Johnson electric regulating apparatus, the thermostat being hung on a crane before the supply register on the third floor. Whatever the temperature in the sub-basement conduits, the air supply to the rooms may be maintained at 70° or 72°, the range being confined within these limits by the automatic action of the regulator.

Within the rooms are placed wall steam pipes, the steam supply to which is regulated by the Johnson automatic apparatus, the thermostat being exposed within the rooms. For the quick warming of the building, the sub-basement conduit temperature may be run up to 100°, and the flue thermostat may be swung away from the register front. Air at such times may be rotated through the building instead of being taken from the outside.

The performance of the apparatus for the automatic regulation of temperature has been satisfactory. The apparatus itself has required but little attention, and the general results in rooms warmed solely by steam surfaces having automatically controlled valves have more than justified the cost of its installation.

The construction and arrangement of the auxiliary heater, Fig. 4, at the base of the flues is a matter of interest, because well suited to a successful working of the automatic method of steam supply. The steam enters at the top and through a valve so throttled that when the main conduit air is at its coldest the steam flow will be nearly continuous. The coil drains through a check valve. Without such an arrangement the temperature within the flue would fluctuate through a considerable range, for on the wide opening of the supply and return valves steam would enter freely at both ends and suddenly heat up

the coil and the flue. It is desirable that the steam flow should be as nearly continuous as possible, and sufficient in quantity to warm the air passing through the coil. If the supply-valve is throttled, the drip-valve must be closed until the pressure within the coil is sufficient to force the accumulated water outward against the steam pressure. A throttled drip-valve would allow steam to back into the coil and cause pounding. But the check-valve holds back the steam and allows the condensation to collect until its weight and the steam pressure combined force the valve open and the water out. The filling of the pipes with condensed water serves also the useful purpose of automatically regulating the length of their heated parts, and aids in maintaining the even temperature sought in the flues.

The heating is for the most part done by the exhaust steam of engines and pumps used in the building, and to avoid the possibility of returning oily water to the boiler the condensation is passed into the sewer. For the purpose of cooling this water, and of utilizing its heat, it is passed through 800 feet of continuous $1\frac{1}{4}$ " pipe, made into a trombone coil 38 pipes high, 7' long, and 3 pipes deep, placed before the inlet window, Fig. 2. In mild weather the condensation is so small that it goes to the sewer cold. When the outside temperature is low that of the chilled water is higher, the rate of condensation slightly exceeding that of the chilling. The maximum rate of flow in severe weather is about 1 cu. ft. per minute.

The fan and combined heater, with directly attached engine, is of the Sturtevant pattern and make, with a large by-pass over the heater. The fan is 6' in diameter, and at 250 revolutions per minute supplies 33,000 cu. ft. of air. Outside the inlet window a roaring sound of rushing air may be heard, due to the high velocities inflicted on the air in transit through the coil and fan because of want of space to give it larger passage and lower velocity. Within this sound is not heard, partly on account of the noise of moving machinery.

The low pressure under which the heating system is worked and the irregular flow of condensed water, due in part to the intermittent supply of steam to the pipes, make the use of any ordinary steam trap impracticable. The method adopted for the relief of the New Building system having given entire satisfaction, it has been adopted in this system also. It consists of a syphon trap made of a 4" pipe 18' long driven vertically into the ground, bushed at the top and tapped at the

side. Through the bushing runs a 2½" pipe to within 1' of the bottom of the large pipe. This pipe is bushed at the top, tapped at the side, and open at the bottom. The tap receives the water from the returns. The bushing receives a 1" pipe, which drains the supply main at a higher pressure than the return, and runs inside the 2½" to within 1' of the bottom of the large pipe. Within the trap there may, therefore, be two pressures and two heights of water columns on the steam side, one vent discharging the water of both. The only resistance or friction is that due to the flow of water through the large pipes.

All steam for the building is brought from the Rogers building through an underground 6" pipe, about 1000' long. The water condensed in the heating apparatus is metered, and the record preserved for the purpose of record and investigation.

The cost of the complete instalment was nearly as follows :—

Fan, engine, main coil (1000 square feet), cooler, &c., . . . *	\$1445
4580 sq. ft. of direct steam surface, flue coils, mains, fittings, and placing, ...	4490
Construction of ducts and sheet-iron work, ...	900
Johnson's electric service, ...	1355
Pump, Locke's regulators, sunken siphon-trap, covering mains, &c., ...	775
Total, ...	<u>\$8,965</u>

The direct heating surface is as great as though the heating of the building depended solely upon it, as insufficient boiler power threatened to make the use of the ventilating system impracticable in severe weather. Furthermore, if air is passed into the rooms at the temperature at which it is desired to keep such rooms, to maintain that temperature, the direct surface must be as large as would be required for heating by direct radiation.

The system is practically a dual one, the capacity of either part being enough for the heating of the building. The ventilating system includes the main heater, cooler, fan, engine, duct, supplementary heaters in flues, &c. Its cost may be put at \$3500, and the balance may be charged to the heating plant. The total heating surface is about 1 sq. ft. to 110 cu. ft. of space.

* This sum includes a gift of \$1000 made to the Institute by Mr. Sturtevant.